Final Exam
AB E 313.3 Instrumentation
April 30, 2003

3 hours **Closed book – no aids**
Answer in booklet provided unless indicated otherwise. **Calculators permitted**

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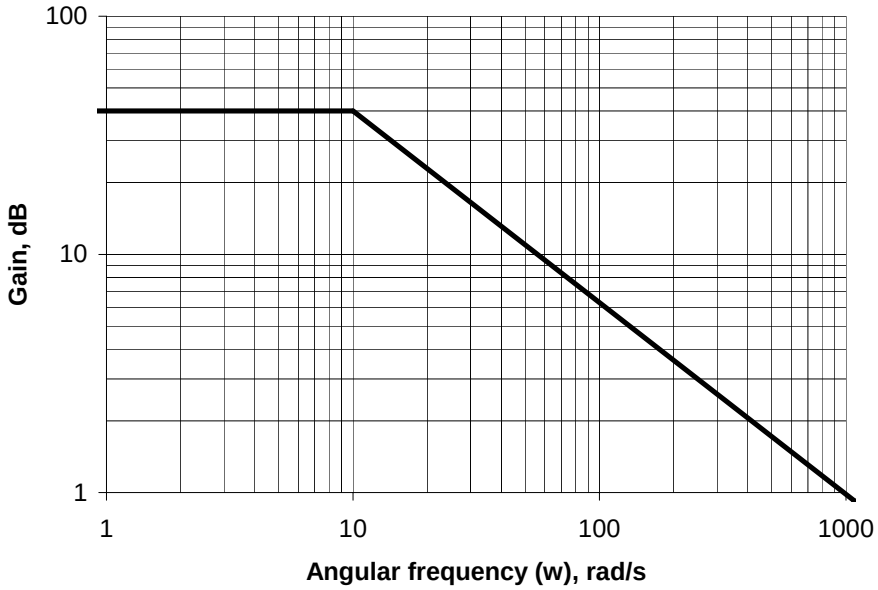
10 1) Define the following, with regard to the material that has been covered in this course.
   a. CMRR
   b. Coefficient of determination
   c. Voltage follower
   d. Zero order system
   e. Gage pressure

10 2) Design a low pass filter (stable integrator) with the frequency characteristic as shown in the following diagram. (Hint: Input impedance of the filter should not be less than 10 kΩ).



Frequency response curve for a low pass filter (not to scale)

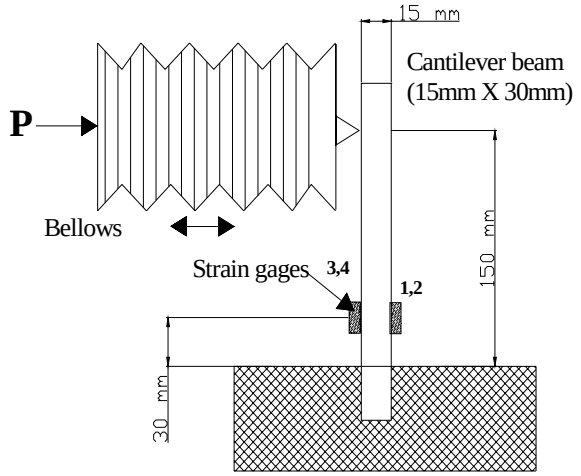
10 3) Explain the principle of operation for a dew point hygrometer (chilled mirror technique). How do you calculate relative humidity using this hygrometer? Show your work using a sketch of a psychrometric chart.

4) Describe the working principles of the following (use figures as necessary).
   a. RTD
   b. McCleod gage
   c. LVDT
   d. Micro manometer
   e. Hot wire anemometer

5) In a uniaxial tension test, a nominal 120-Ω strain gage is mounted on the specimen in the axial direction to record the axial strain. At a certain load, the gage resistance changed to 123.5 Ω. What was the axial strain of the specimen at that gage resistance? Assume the gage factor of the strain gage as 2.

6) A closed, 20-m diameter, cylindrical tank is positioned with its longitudinal axis horizontal. The tank contains water 10 m deep. It has a U – tube mercury manometer connected near the top, which shows vacuum above the water surface of 200 mm Hg. What pressure (in Pa) will a Bourdon tube connected to the bottom of the tank indicate? Specific weight of water = 9810 N/m^3 and one atmosphere = 760 mm Hg.

7) An instrumentation engineer has designed and built a static pressure transducer using one bellows and a cantilever beam (Figure below). Four strain gages (120 Ω each) with gage factor of 2.0 were mounted on a 15 mm x 30 mm (h x b) beam at a height of 30 mm above the fixed base. The bellows point of contact with the beam is 150 mm above the base. The gages are placed in four arms of a wheatstone bridge, so as to obtain maximum output with the output zero when the pressure is atmospheric. Bridge supply voltage is 12 V. The modulus of elasticity for the steel cantilever beam is 200 GPa. Assume the bellows area is 625 mm^2 and it offers no resistance to the applied force. (Hint: For cantilever beam, $\sigma = \frac{My}{I}$; M is bending moment, I is moment of inertia ($\frac{bh^3}{12}$)and y is the fiber distance from neutral axis(h/2)). Find the following
   a. How do you connect the four strain gages into a wheatstone bridge circuit for maximum output (show your work).
   b. Power dissipation in each strain gage (in Watts), when P = atmospheric pressure.
   c. If the bridge output is 40.5 mV, find the pressure, P applied on the bellows.



5 8) You use a K-type thermocouple to sense the temperature of outdoor air under very cold conditions. The Saskatoon weather station reported the outdoor temperature of – 50^{o}C. With one junction of the thermocouple outside, you are measuring the thermal emf inside your research lab using a DMM. The mercury-in-glass thermometer showed the temperature of the research lab is 16^{o}C. What is the expected thermal emf of the thermocouple? Show a sketch of the thermocouple with an indication of the current flow.

5 9) A sinusoidal vibration has a peak displacement of 15 mm and a frequency of 100 Hertz. Calculate the following
   a) velocity and acceleration amplitudes and
   b) the phase relationship between displacement and acceleration.

5 10) Explain why the natural frequency and damping are important factors in accelerometers.

ITS-90 Table for type K thermocouple

°C	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
	Thermoelectric Voltage in mV										
-270	-6.458										
-260	-6.441	-6.444	-6.446	-6.448	-6.45	-6.452	-6.453	-6.455	-6.456	-6.457	-6.458
-250	-6.404	-6.408	-6.413	-6.417	-6.421	-6.425	-6.429	-6.432	-6.435	-6.438	-6.441
-240	-6.344	-6.351	-6.358	-6.364	-6.37	-6.377	-6.382	-6.388	-6.393	-6.399	-6.404
-230	-6.262	-6.271	-6.28	-6.289	-6.297	-6.306	-6.314	-6.322	-6.329	-6.337	-6.344
-220	-6.158	-6.17	-6.181	-6.192	-6.202	-6.213	-6.223	-6.233	-6.243	-6.252	-6.262
-210	-6.035	-6.048	-6.061	-6.074	-6.087	-6.099	-6.111	-6.123	-6.135	-6.147	-6.158
-200	-5.891	-5.907	-5.922	-5.936	-5.951	-5.965	-5.98	-5.994	-6.007	-6.021	-6.035
-190	-5.73	-5.747	-5.763	-5.78	-5.797	-5.813	-5.829	-5.845	-5.861	-5.876	-5.891
-180	-5.55	-5.569	-5.588	-5.606	-5.624	-5.642	-5.66	-5.678	-5.695	-5.713	-5.73
-170	-5.354	-5.374	-5.395	-5.415	-5.435	-5.454	-5.474	-5.493	-5.512	-5.531	-5.55
-160	-5.141	-5.163	-5.185	-5.207	-5.228	-5.25	-5.271	-5.292	-5.313	-5.333	-5.354
-150	-4.913	-4.936	-4.96	-4.983	-5.006	-5.029	-5.052	-5.074	-5.097	-5.119	-5.141
-140	-4.669	-4.694	-4.719	-4.744	-4.768	-4.793	-4.817	-4.841	-4.865	-4.889	-4.913
-130	-4.411	-4.437	-4.463	-4.49	-4.516	-4.542	-4.567	-4.593	-4.618	-4.644	-4.669
-120	-4.138	-4.166	-4.194	-4.221	-4.249	-4.276	-4.303	-4.33	-4.357	-4.384	-4.411
-110	-3.852	-3.882	-3.911	-3.939	-3.968	-3.997	-4.025	-4.054	-4.082	-4.11	-4.138
-100	-3.554	-3.584	-3.614	-3.645	-3.675	-3.705	-3.734	-3.764	-3.794	-3.823	-3.852
-90	-3.243	-3.274	-3.306	-3.337	-3.368	-3.4	-3.431	-3.462	-3.492	-3.523	-3.554
-80	-2.92	-2.953	-2.986	-3.018	-3.05	-3.083	-3.115	-3.147	-3.179	-3.211	-3.243
-70	-2.587	-2.62	-2.654	-2.688	-2.721	-2.755	-2.788	-2.821	-2.854	-2.887	-2.92
-60	-2.243	-2.278	-2.312	-2.347	-2.382	-2.416	-2.45	-2.485	-2.519	-2.553	-2.587
-50	-1.889	-1.925	-1.961	-1.996	-2.032	-2.067	-2.103	-2.138	-2.173	-2.208	-2.243
-40	-1.527	-1.564	-1.6	-1.637	-1.673	-1.709	-1.745	-1.782	-1.818	-1.854	-1.889
-30	-1.156	-1.194	-1.231	-1.268	-1.305	-1.343	-1.38	-1.417	-1.453	-1.49	-1.527
-20	-0.778	-0.816	-0.854	-0.892	-0.93	-0.968	-1.006	-1.043	-1.081	-1.119	-1.156
-10	-0.392	-0.431	-0.47	-0.508	-0.547	-0.586	-0.624	-0.663	-0.701	-0.739	-0.778
0	0	-0.039	-0.079	-0.118	-0.157	-0.197	-0.236	-0.275	-0.314	-0.353	-0.392

°C	0	1	2	3	4	5	6	7	8	9	10
	Thermoelectric Voltage in mV										
0	0	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798
20	0.798	0.838	0.879	0.919	0.96	1	1.041	1.081	1.122	1.163	1.203
30	1.203	1.244	1.285	1.326	1.366	1.407	1.448	1.489	1.53	1.571	1.612
40	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023
50	2.023	2.064	2.106	2.147	2.188	2.23	2.271	2.312	2.354	2.395	2.436
60	2.436	2.478	2.519	2.561	2.602	2.644	2.685	2.727	2.768	2.81	2.851
70	2.851	2.893	2.934	2.976	3.017	3.059	3.1	3.142	3.184	3.225	3.267
80	3.267	3.308	3.35	3.391	3.433	3.474	3.516	3.557	3.599	3.64	3.682
90	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.013	4.055	4.096
100	4.096	4.138	4.179	4.22	4.262	4.303	4.344	4.385	4.427	4.468	4.509
110	4.509	4.55	4.591	4.633	4.674	4.715	4.756	4.797	4.838	4.879	4.92
120	4.92	4.961	5.002	5.043	5.084	5.124	5.165	5.206	5.247	5.288	5.328
130	5.328	5.369	5.41	5.45	5.491	5.532	5.572	5.613	5.653	5.694	5.735
140	5.735	5.775	5.815	5.856	5.896	5.937	5.977	6.017	6.058	6.098	6.138
150	6.138	6.179	6.219	6.259	6.299	6.339	6.38	6.42	6.46	6.5	6.54
160	6.54	6.58	6.62	6.66	6.701	6.741	6.781	6.821	6.861	6.901	6.941
170	6.941	6.981	7.021	7.06	7.1	7.14	7.18	7.22	7.26	7.3	7.34
180	7.34	7.38	7.42	7.46	7.5	7.54	7.579	7.619	7.659	7.699	7.739
190	7.739	7.779	7.819	7.859	7.899	7.939	7.979	8.019	8.059	8.099	8.138
200	8.138	8.178	8.218	8.258	8.298	8.338	8.378	8.418	8.458	8.499	8.539
210	8.539	8.579	8.619	8.659	8.699	8.739	8.779	8.819	8.86	8.9	8.94
220	8.94	8.98	9.02	9.061	9.101	9.141	9.181	9.222	9.262	9.302	9.343
230	9.343	9.383	9.423	9.464	9.504	9.545	9.585	9.626	9.666	9.707	9.747
240	9.747	9.788	9.828	9.869	9.909	9.95	9.991	10.031	10.072	10.113	10.153
250	10.153	10.194	10.235	10.276	10.316	10.357	10.398	10.439	10.48	10.52	10.561
260	10.561	10.602	10.643	10.684	10.725	10.766	10.807	10.848	10.889	10.93	10.971
270	10.971	11.012	11.053	11.094	11.135	11.176	11.217	11.259	11.3	11.341	11.382